Materials Engineering Branch

TIP*

No. 087 Problems with Flexural Pivots

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Flexural pivots are sometimes used on space flight mechanisms as substitutes for bearings when angular rotation is limited to less than 30°. The pivots are made of flat, crossed spring elements attached to rotatable inner and outer sleeves (see Figure 1). Rotational motion is accomplished by twisting the free end about the clamped base. The spring elements are commonly made of Type 420 stainless steel and may be stamped out of sheet stock with resultant sheared edges. In the finished condition, the spring elements are heat treated to a high strength and hardness. Spring elements are joined to the sleeves either by welding or brazing followed by a heat treatment. A number of companies use electron beam (EB) welding as the process of choice.

In many space flight applications, the pivots are required to undergo many millions of oscillations. During the course of acceptance or qualification testing, in a number of cases, pivots develop cracks or even complete breaks in spring elements. Subsequent failure analysis of these cases discloses a variety of deficiencies or defects that cause the failures. These are outlined below:

Decarburization - During the brazing/heat treating process, the furnace atmosphere, if not inert, can react with the carbon in the steel to remove some of the carbon from the outer layer, leaving behind a decarburized zone that has much lower mechanical properties than the original steel. As a consequence, fatigue cracks can easily develop in the decarburized zone which then propagate through the remaining cross-section.

Liquid Metal Embrittlement - In the brazing/heat treating process, the pivot components are assembled and clamped into a fixture with the braze metal electroplated to the spring elements. If the fixturing is such that tensile stresses exist in the elements while the braze metal is molten, then liquid metal may penetrate into the steel along grain boundaries, creating metal-filled cracks. Later cyclic stressing can cause the cracks to open and propagate to failure.

Edge Preparation - Sheared edges that are not properly dressed may result in microscopic stress concentrations being left on the spring element edges that can initiate fatigue cracks under cyclic loading.

Corrosion - A number of stainless steels brazed with silver based filler metals are prone to corrosion, referred to as knife-line attack[1], along the base metal/filler metal interface. It occurs in silver brazed joints in both chromium-nickel and chromium stainless steels when exposed to a moist environment with chloride ions present. It often occurs in silver brazed stainless steels if the brazing flux is not completely removed. This corrosion can occur, in many cases, in the use of tap water

Nondestructive examination of all flex pivots should be done by visual examination at a magnification of at least 10X, preferably higher. To detect decarburization nondestructively, the pivots can be checked for torsional hysteresis to ensure that they remain within the manufacturer's specified limits. Destructive examination of randomly selected samples of each lot of pivots can detect the presence of all of the above defects or deficiencies.

In order to avoid potential complications such as decarburization, liquid metal embrittlement and corrosion only EB welded flex pivots should be used on flight hardware.

Reference: L. E. Samuels, "Optical Microscopy of Carbon Steels", Chapter 12, American Society for Metals.

[1] Also called interface corrosion.

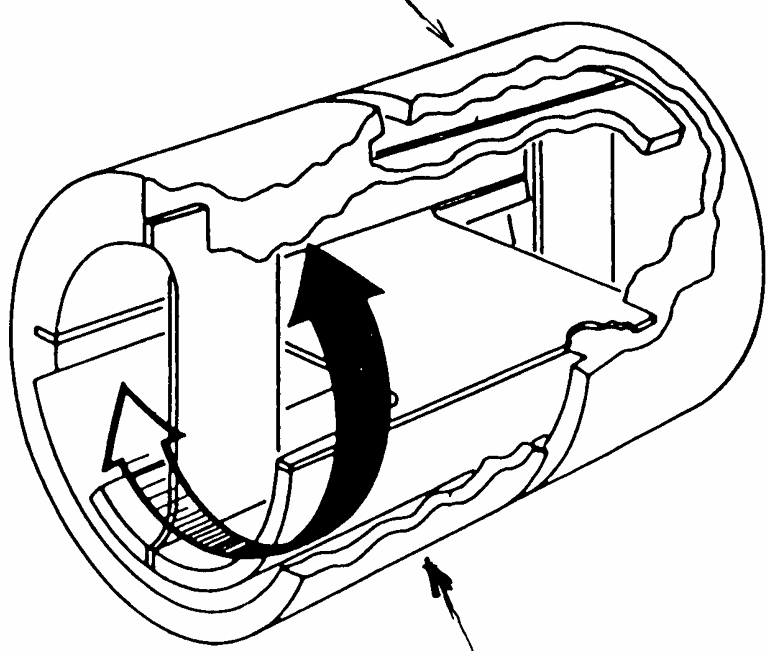

Figure 1. Illustration of a flex(ural) pivot.